

What is claimed is:

1. A gas chromatograph having four or more analysis channels for simultaneous
5 analysis of four or more fluid samples, the gas chromatograph comprising
four or more gas chromatography columns, each of the four or more gas
chromatography columns comprising an inlet for receiving a gaseous mobile phase that
includes a gaseous sample, a separation media effective for separating at least one
component of the sample from other components thereof, and an outlet for discharging
10 the separated sample, and

a microdetector array comprising four or more microfabricated microdetectors
integral with a substrate or with one or more microchip bodies mounted on the substrate,
the four or more microdetectors having an inlet port in fluid communication with the
outlet one or more of the gas chromatography columns for receiving a separated sample,
15 a detection cavity for detecting at least one component of the separated sample, and an
outlet port for discharging the sample.

2. The gas chromatograph of claim 1 wherein the four or more microdetectors each
have a sensitivity for detecting a component of interest, the sensitivity varying less than
20 about 10% between the four or more microdetectors.

3. The gas chromatograph of claim 1 wherein the four or more microdetectors are
integral with the substrate.

25 4. The gas chromatograph of claim 1 wherein the four or more microdetectors are
integral with one or more microchip bodies mounted on the substrate.

5. The gas chromatograph of claim 4 wherein the one or more microchip bodies are
detachably mounted on the substrate.

6. The gas chromatograph of claim 1 wherein the four or more microdetectors are selected from the group consisting of thermal conductivity detectors, photoionization detectors, optical emission detectors, flame ionization detectors, surface acoustic wave detectors and pulse discharge detectors.

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7. The gas chromatograph of claim 1 wherein the four or more microdetectors are thermal conductivity detectors.

8. The gas chromatograph of claim 1 wherein the four or more microdetectors are thermal conductivity detectors, and each of the four or more thermal conductivity detectors comprise a detection cavity and a thin-film detection filament within the detection cavity.

9. The gas chromatograph of claim 1 wherein the microdetectors are microfabricated in a plurality of silicon laminae using microfabrication techniques selected from the group consisting of oxidation, masking, etching, thin-film deposition, planarization and bonding.

10. A gas chromatograph having four or more analysis channels for simultaneous analysis of four or more fluid samples, the gas chromatograph comprising four or more gas chromatography columns, each of the four or more gas chromatography columns comprising an inlet for receiving a gaseous mobile phase that includes a gaseous sample, a separation media effective for separating at least one component of the sample from other components thereof, and an outlet for discharging the separated sample, and

a microdetector array comprising four or more thermal conductivity detectors integral with or mounted on a substrate, each of the four or more thermal conductivity detectors having an inlet port in fluid communication with the outlet one or more of the gas chromatography columns for receiving a separated sample, a detection cavity

comprising a thin-film detection filament within the detection cavity for detecting at least one component of the separated sample, and an outlet port for discharging the sample.

11. The gas chromatograph of claim 10 wherein the four or more detection filaments
5 have a temperature-dependent resistance, and the four or more thermal conductivity detectors each have a thermal coefficient of resistance that varies less than about 10% between the four or more thermal conductivity detectors.

12. The gas chromatograph of claim 10 wherein the detection filament of each of the
10 four or more thermal conductivity detectors has a resistance that varies less than about 25% between the four or more thermal conductivity detectors.

13. The gas chromatograph of claim 10 wherein the thin-film detection filament
15 comprises a film of material having a temperature-dependent resistance on a support bridge.

14. The gas chromatograph of claim 10 wherein the four or more microdetectors are integral with the substrate.

20 15. The gas chromatograph of claim 14 wherein each of the four or more microdetectors are formed in a substrate comprising one or more laminae and having an exterior surface, and the inlet port and outlet port of the microdetectors each comprise an interior wall substantially normal to the exterior surface of the substrate.

25 16. The gas chromatograph of claim 10 wherein the four or more microdetectors are mounted on the substrate.

17. The gas chromatograph of claim 16 wherein the four or more microdetectors are detachably mounted on the substrate.

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18. The gas chromatograph of claims 16 or 17 wherein the four or more microdetectors are mounted individually on the substrate.

19. The gas chromatograph of claims 16 or 17 wherein the four or more
5 microdetectors are mounted on the substrate as one or more modules, each of the one or more modules comprising two or more microdetectors.

20. The gas chromatograph of claims 16 or 17 wherein the four or more thermal conductivity detectors are integral with one or more microchip bodies mounted on the
10 substrate, each of the one or more microchip bodies comprising one or more microdetectors.

21. The gas chromatograph of claim 16 wherein the four or more thermal conductivity detectors are integral with one or more microchip bodies bonded to the
15 substrate, each of the one or more microchip bodies comprising one or more microdetectors.

22. The gas chromatograph of claim 17 wherein the four or more thermal conductivity detectors are integral with one or more microchip bodies detachably
20 mounted on the substrate, each of the one or more microchip bodies comprising one or more microdetectors.

23. The gas chromatograph of claim 22 wherein the microdetector array further comprises
25 four or more pairs of passages formed in the substrate for fluid communication with the four or more microdetectors, respectively, each pair of passages comprising a first inlet passage for fluid communication with the inlet port of one of the microdetectors, and a second outlet passage for fluid communication with the outlet port of the one of the microdetectors, and

one or more releasable seals situated between the substrate and the one or more microchip bodies.

24. The gas chromatograph of claim 23 wherein the one or more releasable seals
5 comprises four or more pairs of o-rings for releasably sealing the inlet passages and outlet passages of the substrate with the corresponding inlet ports and outlet ports of the microdetectors, respectively.

25. The gas chromatograph of claim 23 wherein the one or more releasable seals
10 comprises one or more gaskets for releasably sealing the inlet passages and outlet passages of the substrate with the corresponding inlet ports and outlet ports of the microdetectors, respectively.

26. The gas chromatograph of claim 10 wherein the each of the four or more thermal
15 conductivity detectors further comprise first and second electrical contacts for electrical communication with an integral or an external signal-processing circuit, a first conductive path between the first electrical contact and a first end of the detection filament, and a second conductive path between the second electrical contact and a second end of the detection filament.

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27. The gas chromatograph of claim 10 wherein the microdetector array further comprises at least one reference thermal conductivity detector, the at least one reference detector having an inlet port in fluid communication with a reference gas source for receiving a reference gas, a detection cavity comprising a thin-film detection filament
25 within the detection cavity for detecting the reference gas, and an outlet port for discharging the detected reference gas, the ratio of the number of gaseous sample detectors to the number of reference detector(s) being at least 2:1.

28. The gas chromatograph of claims 10 or 17 wherein the four or more thermal conductivity detectors are arranged to have a planar density of at least about 1 thermal conductivity detector per 10 cm².

5 29. The gas chromatograph of claims 10 or 17 wherein the four or more thermal conductivity detectors comprise six or more thermal conductivity detectors.

30. The gas chromatograph of claims 3 or 10 wherein the four or more thermal conductivity detectors comprise six or more thermal conductivity detectors arranged to
10 have a planar density of at least about 1 thermal conductivity detector per 1 cm².

31. The gas chromatograph of claims 3 or 10 wherein the volume of the detection cavity of each of the four or more thermal conductivity detectors ranges from about 1 µl to about 500 µl.

15 32. A gas chromatograph for simultaneous analysis of six or more fluid samples, the gas chromatograph comprising

six or more gas chromatography columns, each of the six or more gas chromatography columns comprising an inlet for receiving a gaseous mobile phase that
20 includes a gaseous sample, a separation media effective for separating at least one component of the sample from other components thereof, and an outlet for discharging the mobile phase and the separated sample, and

a microdetector array comprising six or more sample thermal conductivity detectors and at least one reference thermal conductivity detector, each of the sample and
25 reference thermal conductivity detectors being integral with or mounted on a substrate with a planar density of at least about 1 thermal conductivity detector per 1 cm², the ratio of sample detectors to reference detector(s) being at least 2:1,

each of the six or more sample thermal conductivity detectors having an inlet port in fluid communication with the outlet of one of the gas chromatography columns for
30 receiving a separated sample, a detection cavity having a volume ranging from about 1 µl

to about 500 μ l for detecting at least one component of the separated sample, a thin-film detection filament within the detection cavity, the detection filament having a temperature-dependent resistance, an outlet port for discharging the sample, a first conductive path between the a first end of the detection filament and a first electrical contact, and a second conductive path between a second end of the detection filament and a second electrical contact, the first and second electrical contacts being adapted for electrical communication with one or more integral or external signal-processing circuits,

the at least one reference thermal conductivity detector having an inlet port in fluid communication with a reference gas source for receiving a reference gas, a detection cavity comprising a thin-film detection filament within the detection cavity for detecting the reference gas, and an outlet port for discharging the detected reference gas,

the six or more sample thermal conductivity detectors each having a thermal coefficient of resistance that varies less than about 10% between the six or more thermal conductivity detectors.

33. The gas chromatograph of claim 24 wherein the six or more sample thermal conductivity microdetectors are integral with one or more microchip bodies, each of the one or more microchip bodies comprising one or more microdetectors, the microchip bodies being detachably mounted on a first mounting surface of the substrate, the first and second electrical contacts being situated on a first exposed surface of the microchip bodies, the first exposed surface of the microchip bodies being substantially parallel to a second mounting surface of the microchip bodies, the inlet port and the outlet port of the sample thermal conductivity microdetectors being substantially normal to the second mounting surface of the microchip bodies, the microdetector array further comprising

six or more pairs of passages formed in the substrate for fluid communication with the six or more thermal conductivity microdetectors, respectively, each pair of passages comprising a first inlet passage for fluid communication with the inlet port of one of the thermal conductivity microdetectors, and a second outlet passage for fluid communication with the outlet port of one of the thermal conductivity microdetectors,

one or more releasable seals situated between the first mounting surface of the substrate and the second mounting surface of the one or more microchip bodies,

one or more signal processing circuits for measuring the temperature-dependent resistance of each of the detection filaments, and

5 an array of electrical contact pins adapted to contact the electrical contacts at the first exposed surface of the one or more microchip bodies for providing electrical communication between the one or more signal processing circuits and the first and second electrical contacts of the six or more thermal conductivity microdetectors.

10 34. The gas chromatograph of claim 10 further comprising a parallel injector, the parallel injector comprising one or more injection valves adapted to substantially simultaneous inject four or more gaseous samples into the respective mobile phase of the four or more gas chromatography columns.

15 35. The gas chromatograph of claim 34 further comprising a parallel vaporizer, the parallel vaporizer comprising four or more injection ports for receiving four or more liquid samples, respectively, and four or more vaporization chambers for substantially simultaneously vaporizing four or more liquid samples to form the four or more gaseous samples.

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36. The gas chromatograph of claim 35 wherein the parallel vaporizer is integral with the parallel injector.

25 37. The gas chromatograph of claims 1, 10, 17, 23 or 32 wherein the four or more gas chromatography columns are capillary gas chromatography columns.

38. The gas chromatograph of claims 1, 10, 17, 23 or 32 wherein the four or more gas chromatography columns are microfluidic channels comprising the separation medium.

39. The gas chromatograph of claims 1 or 10 wherein the gas chromatograph comprises eight or more gas chromatography columns in a heated environment, the heated environment comprising a convection zone for directed flow of a fluid in a substantially uniform direction past the eight or more gas chromatography columns.

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40. The gas chromatograph of claims 7 or 10 wherein the detection cavity comprises two or more detection filaments.

41. An apparatus comprising

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the gas chromatograph of claims 1, 10, 17, 23 or 32 and

a parallel flow reactor having four or more reaction vessels, each of the four or more reaction vessels comprising an inlet for feeding reactants into the reaction vessel, a reaction zone for effecting a chemical reaction, and an outlet for discharging reaction products and unreacted reactants, if any, the outlets of the four or more reaction vessels
15 being in at least sampling fluid communication with the inlets of the four or more gas chromatography columns, respectively.

42. A microdetector array comprising

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four or more thermal conductivity microdetectors detectors integral with or mounted on a substrate with a planar density of at least about 1 thermal conductivity detector per 10 cm^2 , each of said thermal conductivity detectors comprising

a detection cavity having a volume of not more than about $500\text{ }\mu\text{l}$,

an inlet port for admitting a fluid sample into the detection cavity,

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a thin-film detection filament within the detection cavity, the detection filament having a temperature-dependent resistance,

an outlet port for discharging a fluid sample from the detection cavity,

first and second electrical contacts for electrical communication with a signal-processing circuit,

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a first conductive path between the first electrical contact and a first end of the detection filament, and

a second conductive path between the second electrical contact and a second end of the detection filament.

43. The array of claim 42 wherein the four or more thermal conductivity detectors
5 each have a thermal coefficient of resistance that varies less than about 10% between the four or more thermal conductivity detectors.

44. The array of claim 42 wherein the detection filament of each of the four or more thermal conductivity detectors has a resistance that varies less than about 25% between
10 the four or more thermal conductivity detectors.

45. The array of claim 42 wherein the four or more microdetectors are integral with the substrate.

15 46. The array of claim 42 wherein the four or more microdetectors are mounted on the substrate.

47. The array of claim 42 wherein the four or more microdetectors are detachably mounted on the substrate.

20 48. The array of claims 46 or 47 wherein the four or more thermal conductivity detectors are integral with one or more microchip bodies mounted on the substrate, each of the one or more microchip bodies comprising one or more microdetectors.

25 49. The array of claim 46 wherein the four or more thermal conductivity detectors are integral with one or more microchip bodies bonded to the substrate, each of the one or more microchip bodies comprising one or more microdetectors.

50. The array of claim 47 wherein the four or more thermal conductivity detectors are integral with one or more microchip bodies detachably mounted on the substrate, each of the one or more microchip bodies comprising one or more microdetectors.

5 51. The array of claim 50 wherein the microdetector array further comprises
four or more pairs of passages formed in the substrate for fluid communication
with the four or more microdetectors, respectively, each pair of passages comprising a
first inlet passage for fluid communication with the inlet port of one of the
microdetectors, and a second outlet passage for fluid communication with the outlet port
10 of the one of the microdetectors, and
one or more releasable seals situated between the substrate and four or more
microdetectors.

15 52. The array of claim 50 wherein the first and second electrical contacts are situated
on a first exposed surface of the one or more microchip bodies, and the inlet port and the
outlet port of the thermal conductivity detectors are substantially normal to an opposing
second surface of the microchip bodies.

20 53. The array of claim 42 wherein the four or more thermal conductivity detectors are
arranged to have a planar density of at least about 1 thermal conductivity detector per 1
cm².

25 54. The array of claim 42 wherein the volume of the detection cavity of each of the
four or more thermal conductivity detectors ranges from about 1 μ l to about 500 μ l.

55. A method for parallel analysis of four or more fluid samples by gas
chromatography, the method comprising
injecting four or more gaseous samples into respective mobile phases of four or
more gas chromatography columns,

contacting the four or more gaseous samples with separation media in the respective gas chromatography columns to separate at least one analyte from other constituents of the gaseous samples, and

detecting the four or more separated analytes with a microdetector array
5 comprising four or more microfabricated microdetectors.

56. The method of claim 55 wherein the injecting, contacting and detecting steps are effected with the gas chromatograph of any of claims 1, 5, 7 or 8.

10 57. The method of claim 55 wherein the injecting, contacting and detecting steps are effected with the gas chromatograph of any of claims 10, 17, 23 or 32.

58. The method of claim 55 wherein the four or more fluid samples are four or more liquid samples, the method further comprising

15 injecting the four or more liquid samples into the injection ports of the parallel vaporizer, and

substantially simultaneously vaporizing the four or more liquid samples to form four or more gaseous samples.

20 59. The method of claim 55 wherein the four or more fluid samples are four or more gaseous samples discharged from a parallel flow reactor comprising four or more reaction channels.

60. A method for evaluating the catalytic performance of candidate catalysts, the
25 method comprising
simultaneously contacting four or more candidate catalysts with one or more reactants in a parallel reactor under reaction conditions to catalyze at least one reaction, and

detecting the resulting reaction products or unreacted reactants in parallel with the gas chromatograph of claims 1, 10, 17, 23 or 32 to determine the relative performance of
30 the candidate catalysts.

61. The method of claim 56 wherein the four or more of candidate catalysts have different compositions.

5 62. The method of claim 56 wherein the four or more candidate catalysts are contacted with the one or more reactants under different reaction conditions.

63. A gas chromatograph having eight or more analysis channels for simultaneous analysis of eight or more fluid samples, the gas chromatograph comprising
10 eight or more gas chromatography columns residing in a heated environment, each of the eight or more gas chromatography columns comprising an inlet for receiving a gaseous mobile phase that includes a gaseous sample, a separation media effective for separating at least one component of the sample from other components thereof, and an outlet for discharging the separated sample, the heated environment comprising a forced
15 convection zone for directed flow of a fluid in a substantially uniform direction past the eight or more gas chromatography columns, and
a detector array comprising eight or more detectors, the eight or more detectors each having an inlet port in fluid communication with the outlet of one or more of the gas chromatography columns for receiving a separated sample, a detection cavity for
20 detecting at least one component of the separated sample, and an outlet port for discharging the sample.

64. The gas chromatograph of claim 63 wherein the convection zone is defined by a zone of substantially uniformly directed turbulent fluid flow between two or more
25 convection fans.

65. The gas chromatograph of claim 63 wherein the convection zone is defined by a zone of substantially uniformly directed turbulent fluid flow created by two or more convection fans on opposing sides of the eight or more gas chromatography columns.

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66. The gas chromatograph of claim 65 wherein the convection zone is further defined by a chimney adapted to direct the fluid flow within the chimney from one or more convection fans on first side of the eight or more gas chromatography columns to one or more opposing convection fans on an opposing second side of the eight or more gas chromatography columns, with the gas chromatography columns being internal or external to the chimney.

67. The gas chromatograph of claim 66 wherein a first convection fan is a radial convection fan and a second convection fan is an axial convection fan.

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68. The gas chromatograph of claim 63 comprising sixteen or more gas chromatography columns in the heated environment.